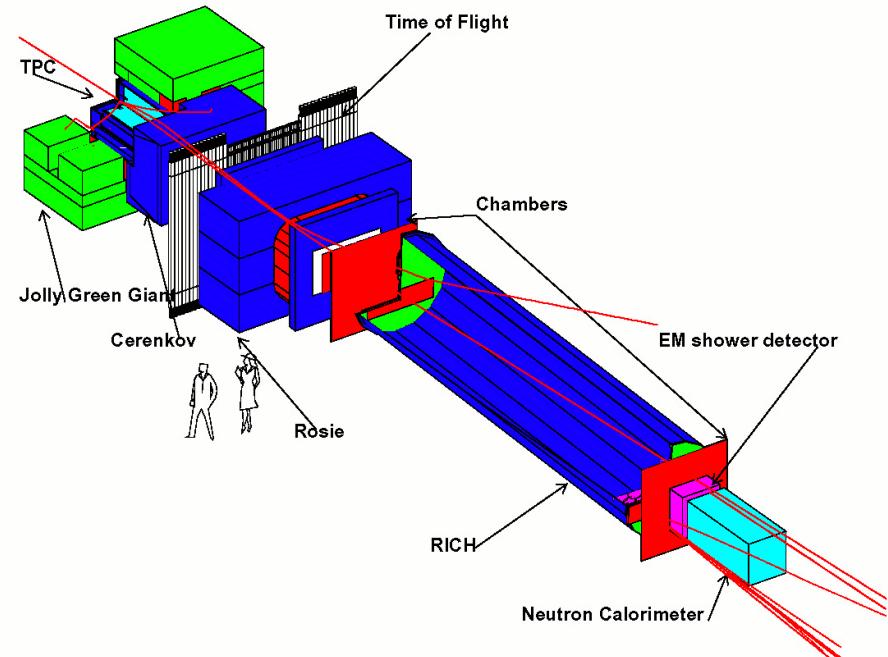
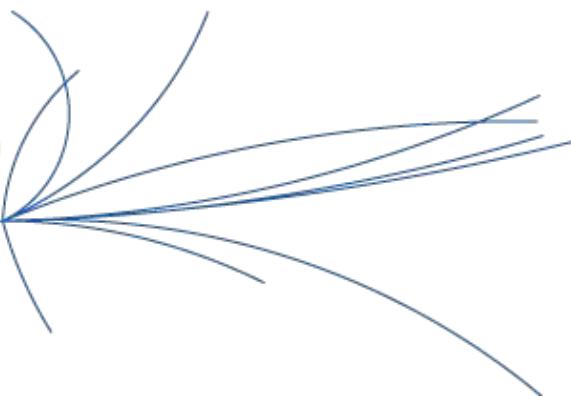


# Hadronic Cross Sections for Neutrino Production in

**MIPP**

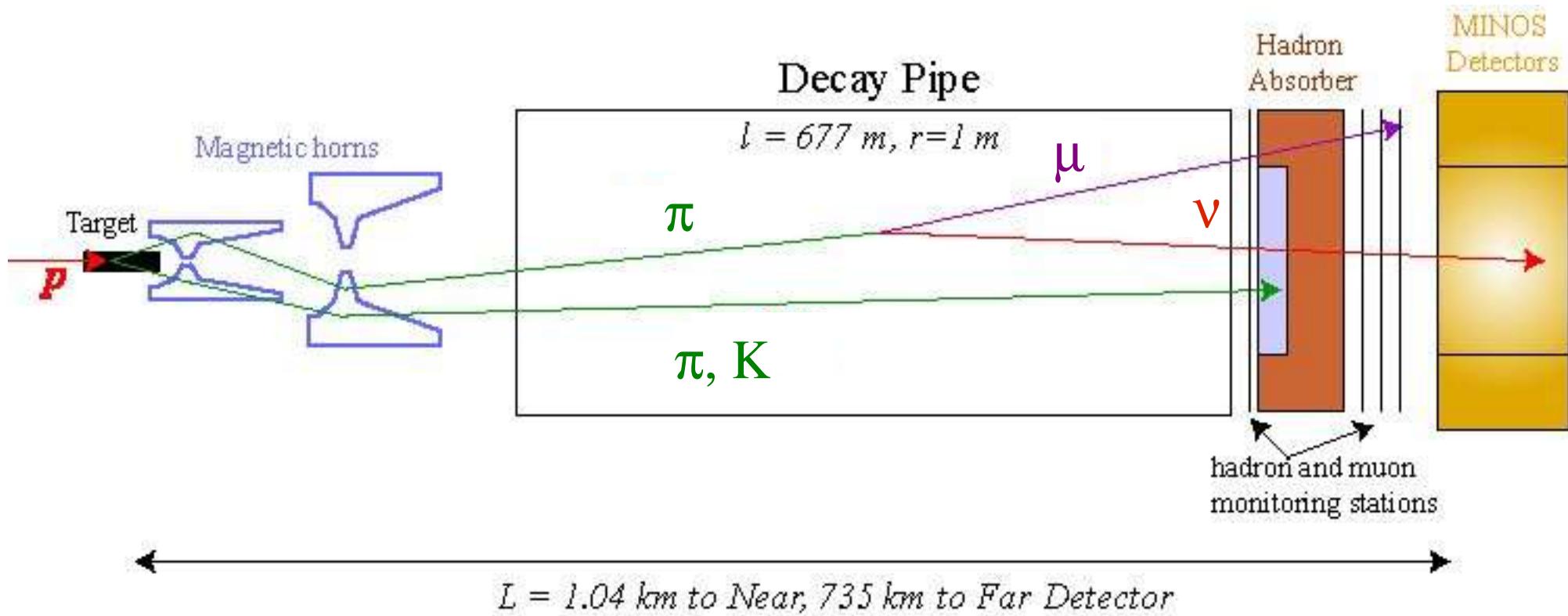


Jonathan M. Paley

PANIC '05  
10/25/05

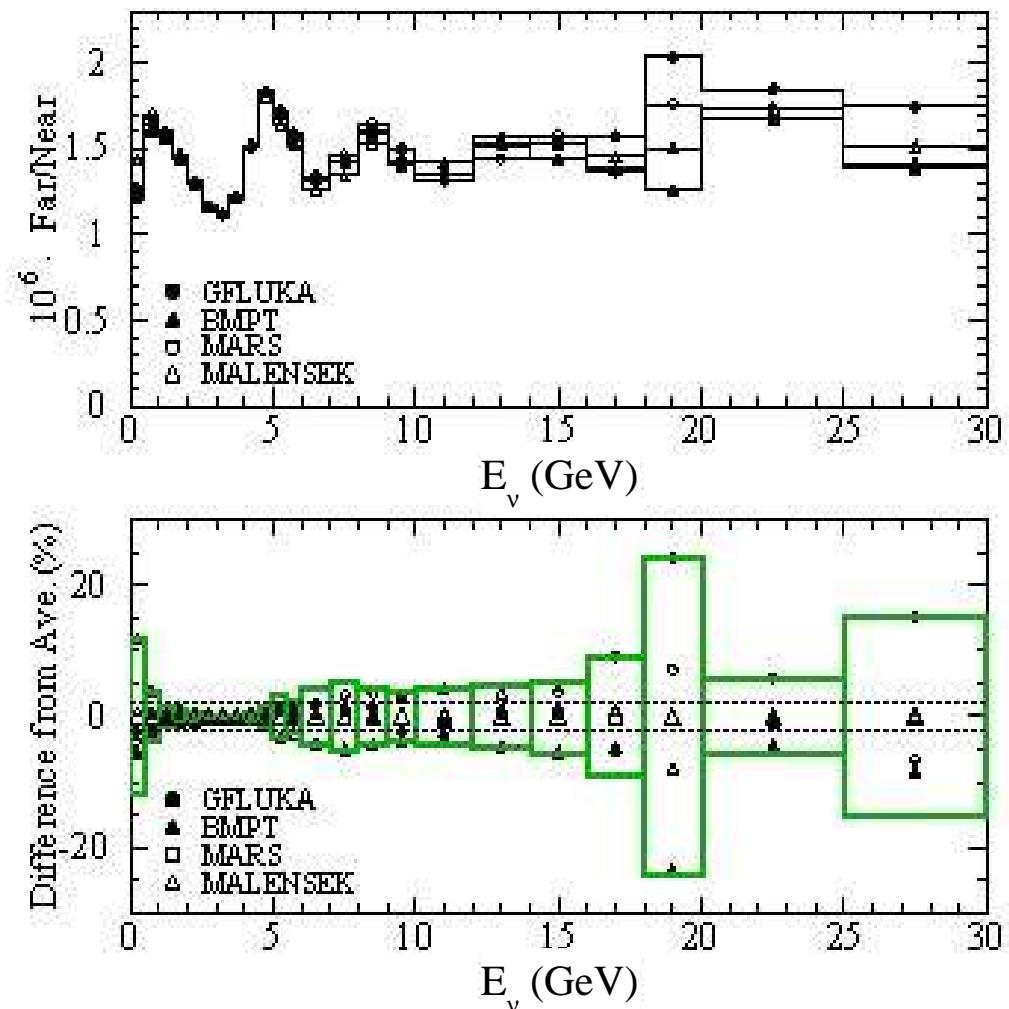
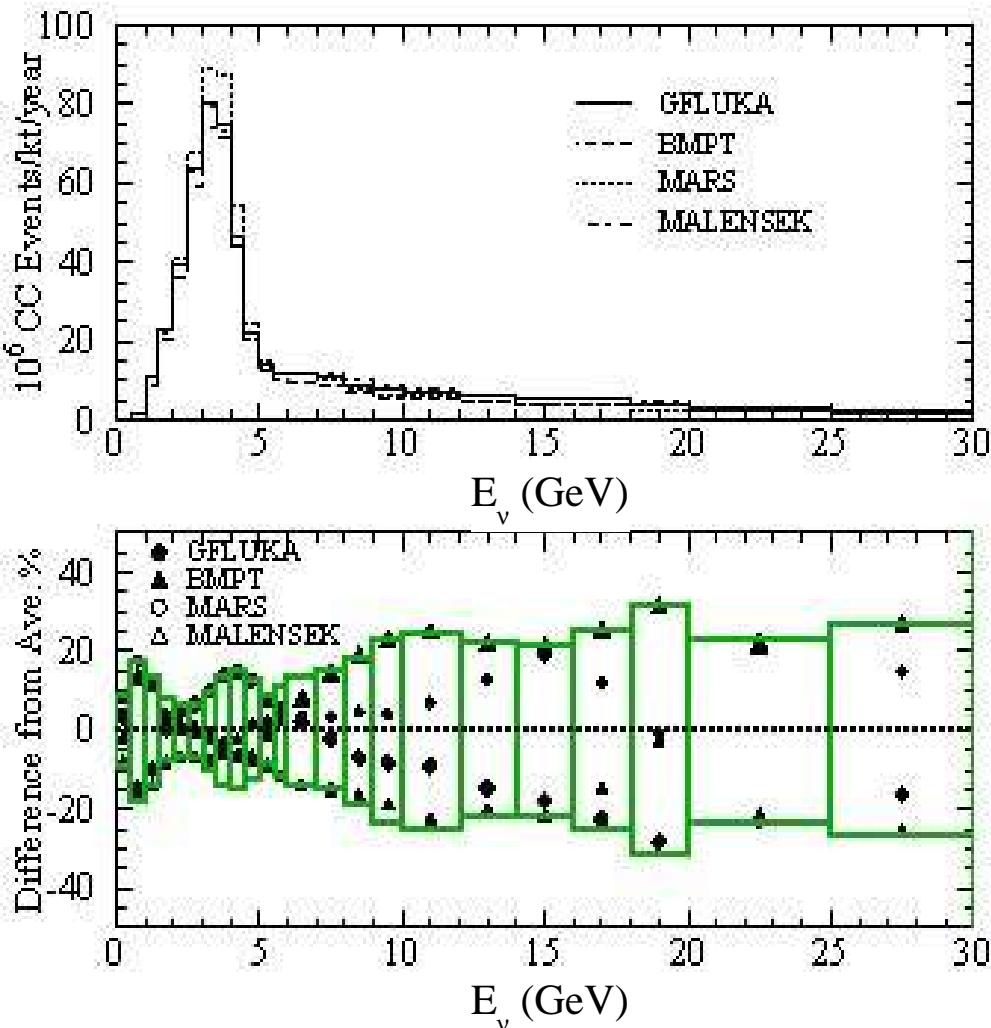
Indiana University

# Why are Hadron Production Data Important?



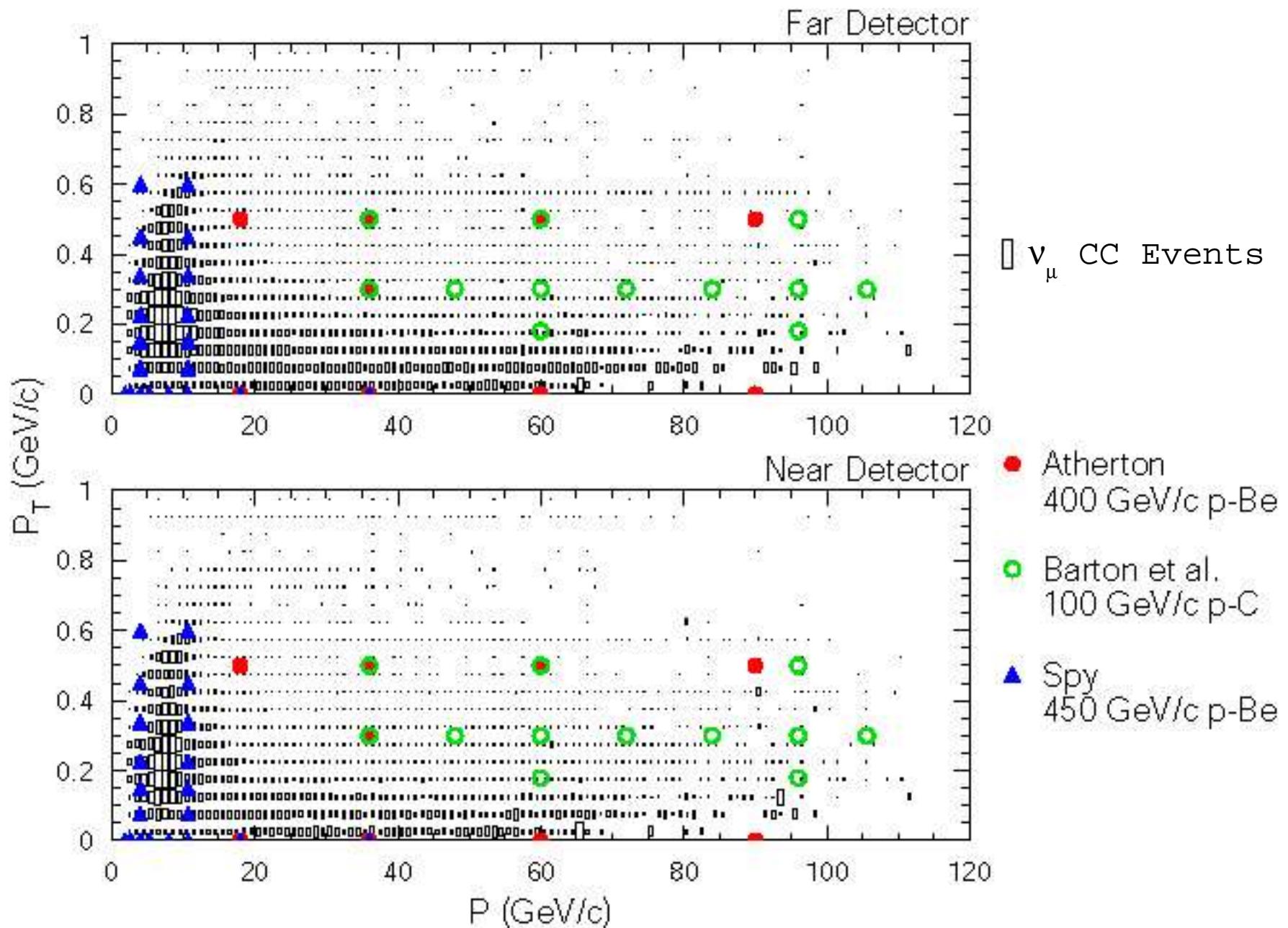
- Many neutrino experiments rely on Monte Carlo predictions of flux
- Neutrinos come from meson decay
- Important for long baseline, atmospheric neutrino measurements and neutrino cross-section measurements (e.g.: Minerva)

# MINOS/NuMI MC Flux Predictions



Highly correlated models result in predictions that differ by up to ~20%...

# Existing Hadron Production Data



**Detector:** TPC

TPC

PID Momentum:

< 1 GeV/c

ToF

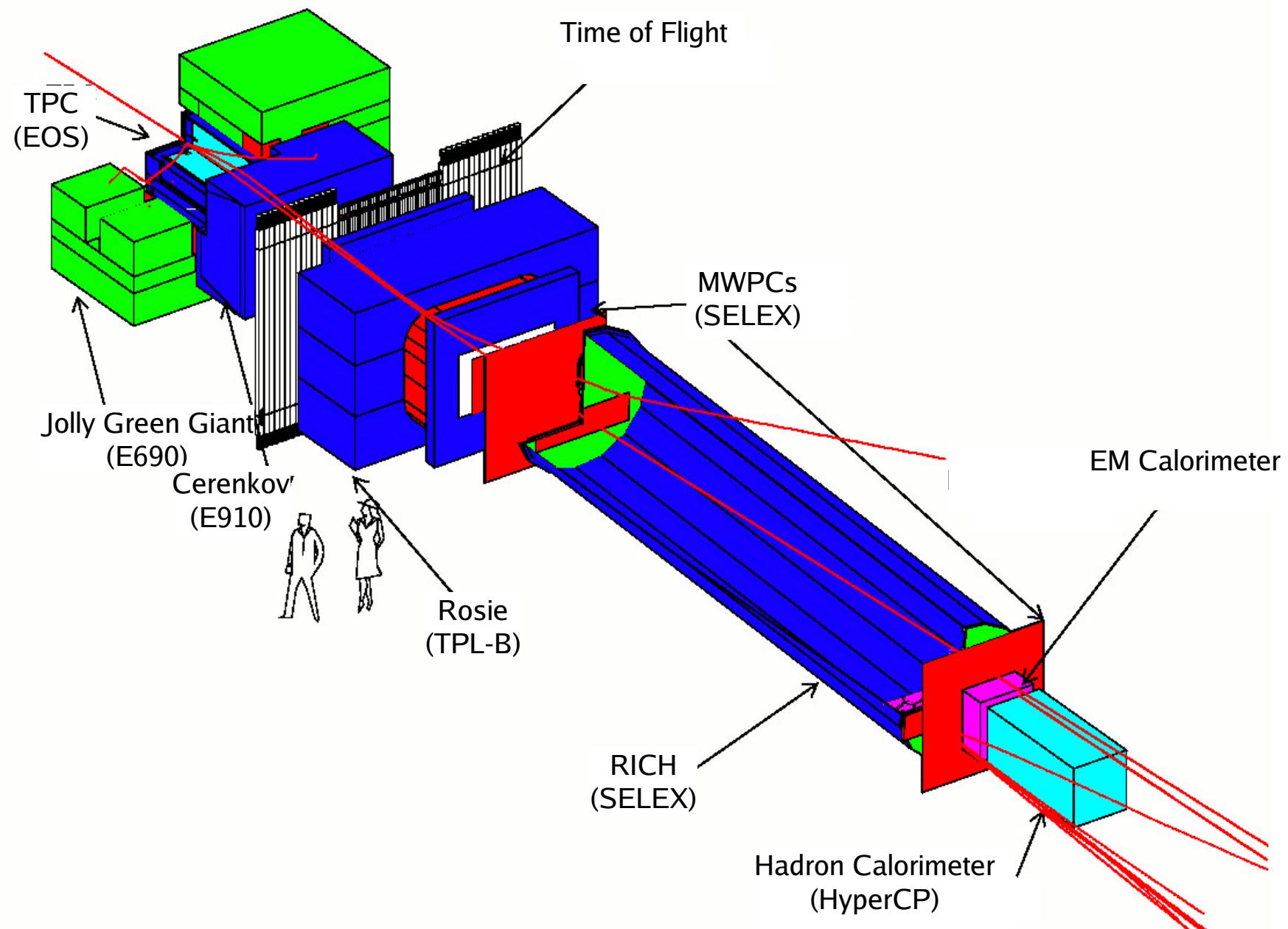
1-3 GeV/c

DCkov

3-17 GeV/c

RICH

20-80 GeV/c

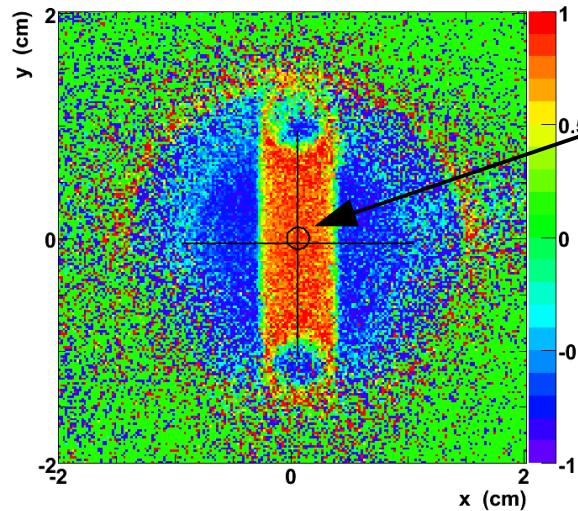


# Main Injector Particle Production (MIPP) Experiment:

- full acceptance spectrometer
- excellent particle ID
- hadron production (HP) cross-section measurements
- measure HP off NuMI target

Target Z/Element	Momentum (GeV/c)								Total	
	-84	-58	-35	-20	20	35	58	84		
1 / H	0.49	0.51		0.40	0.52		1.2	0.51	3.63	
4 / Be		0.3	0.08			0.12	0.26		1.00	1.76
6 / C*					0.39	0.08	0.4		0.49	1.36
NuMI**									1.50	1.50
83 / Bi		0.55	0.26			0.26	0.51		1.00	2.58
Total	0.49	1.36	0.34	0.40	0.91	0.46	2.37	0.51	3.99	10.83

# The NuMI Target in MIPP

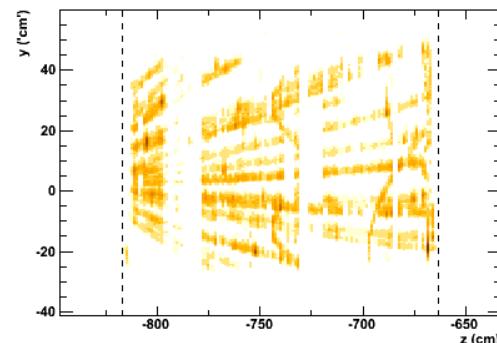
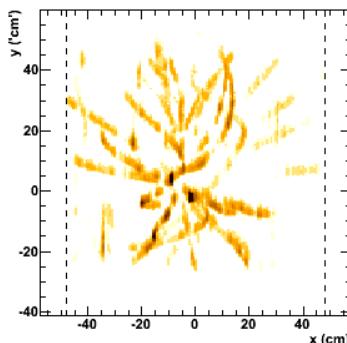


Beam aligned to within 0.5 mm of the target center  
( $\Delta x = 0.002$  cm,  $\Delta y = 0.051$  cm )

Raw TPC Event

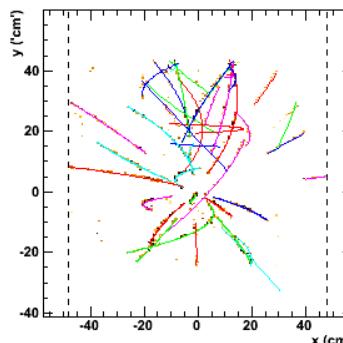
Reconstructed TPC Event

MIPP (FNAL E907)  
Mom.: 120 GeV/c  
Target: NuMI  
Run: 15203  
SubRun: 0  
Event: 1000  
Fri Jul 29 2005  
19:16:34.519570  
\*\*\* Trigger \*\*\*  
Beam  
Word: 0080  
Bits: 80D7



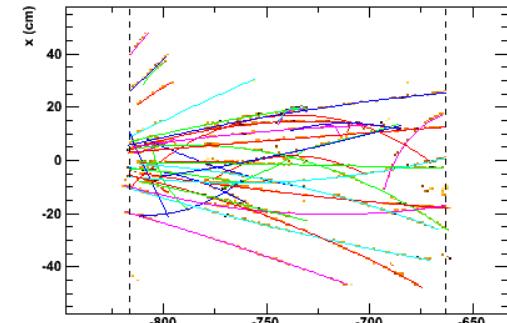
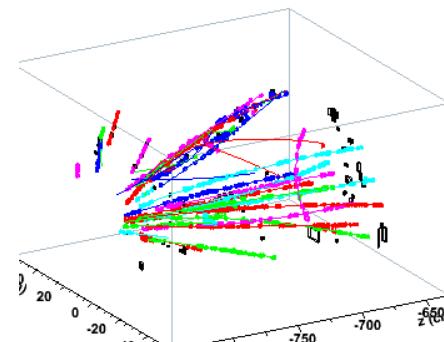
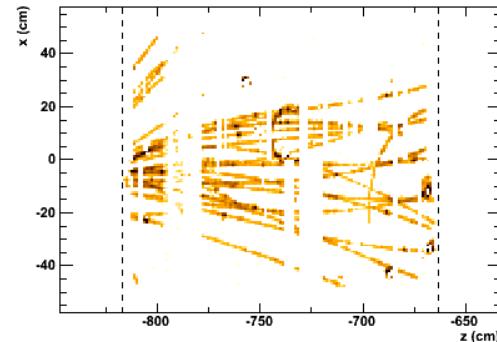
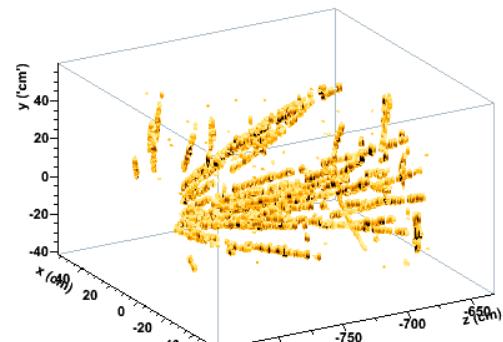
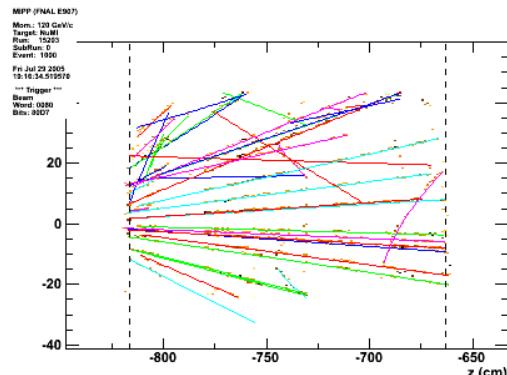
FNAL E907

120 GeV/c  
NuMI  
15203  
n: 0  
1000  
29.05.14.519570  
Trigger \*\*\*  
0080  
80D7

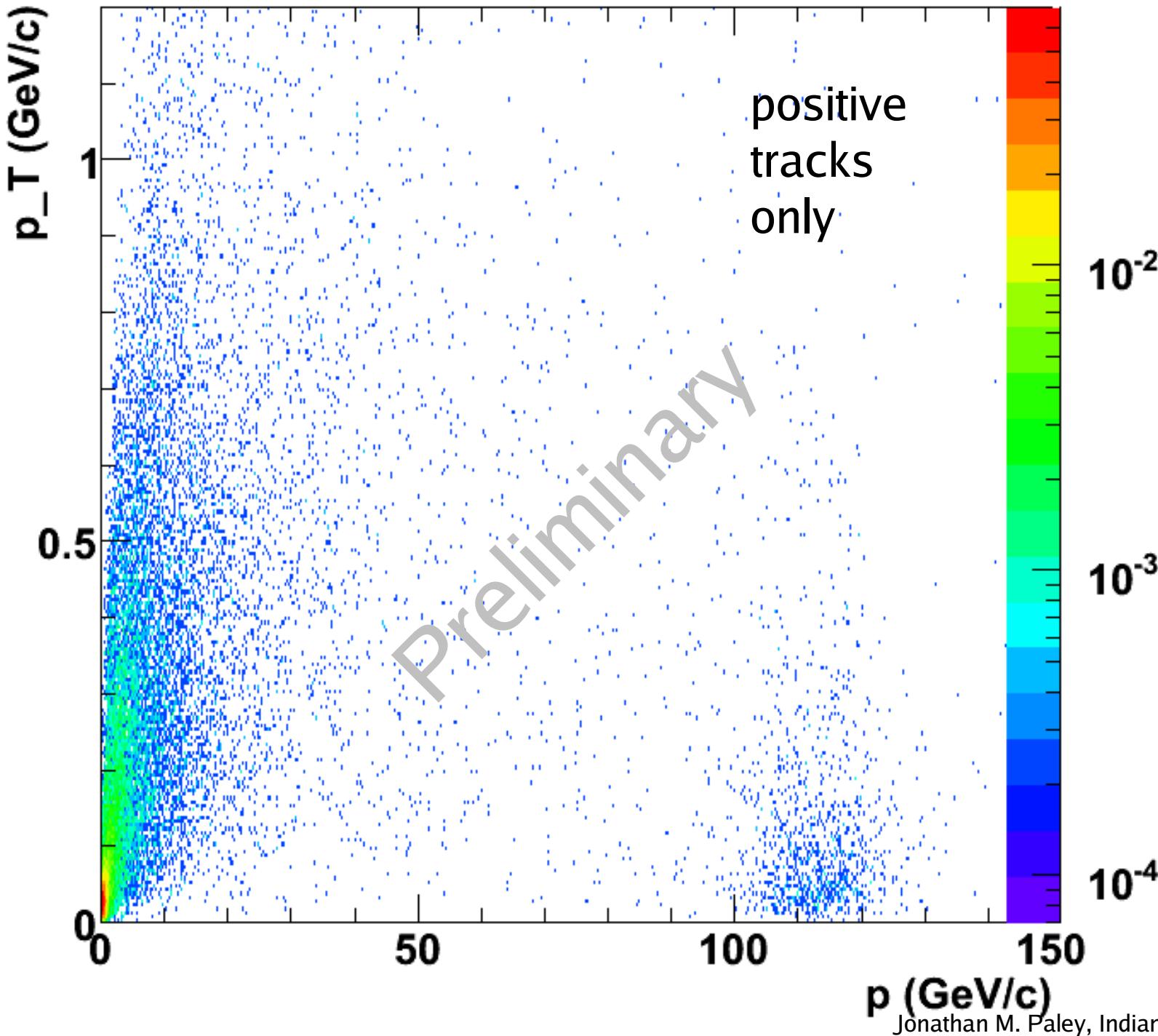


MIPP (FNAL E907)

Mom.: 120 GeV/c  
Target: NuMI  
Run: 15203  
SubRun: 0  
Event: 1000  
Fri Jul 29 2005  
19:16:34.519570  
\*\*\* Trigger \*\*\*  
Beam  
Word: 0080  
Bits: 80D7



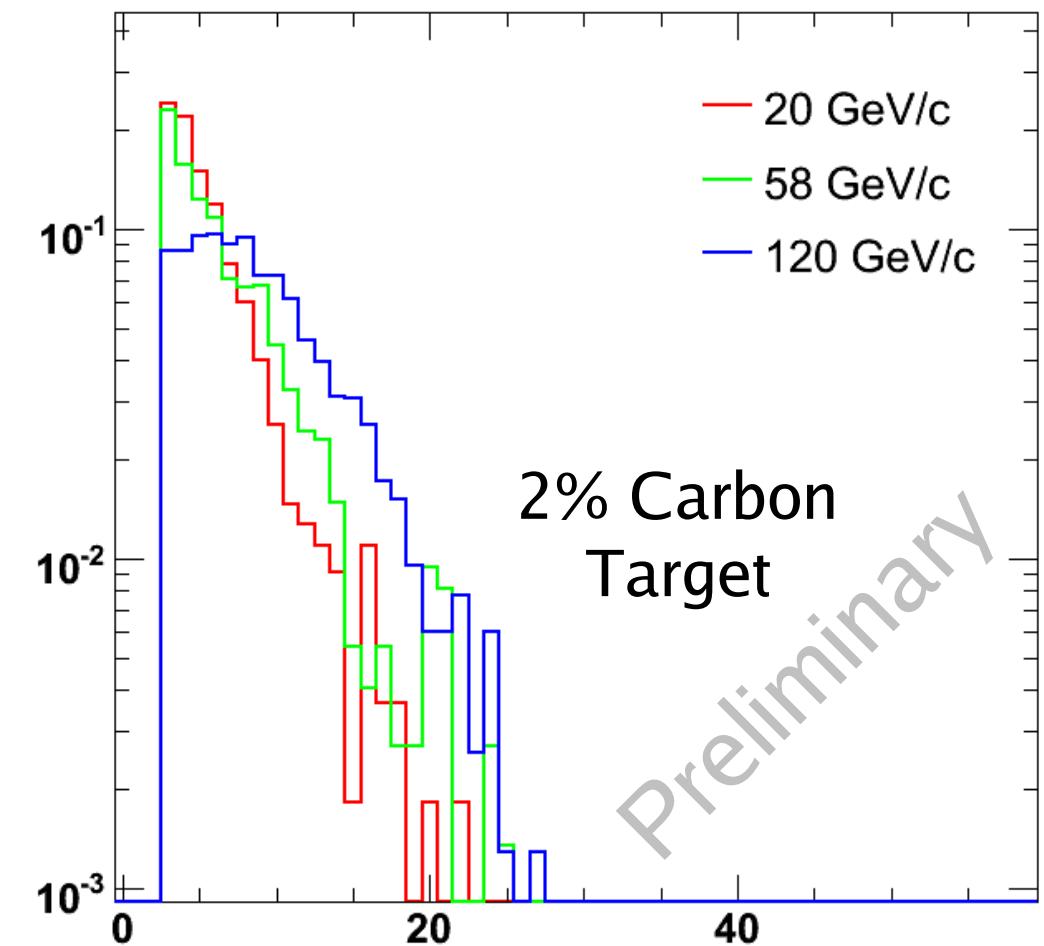
# 120 GeV C + NuMI Target $p_T$ vs. $p$ Distribution



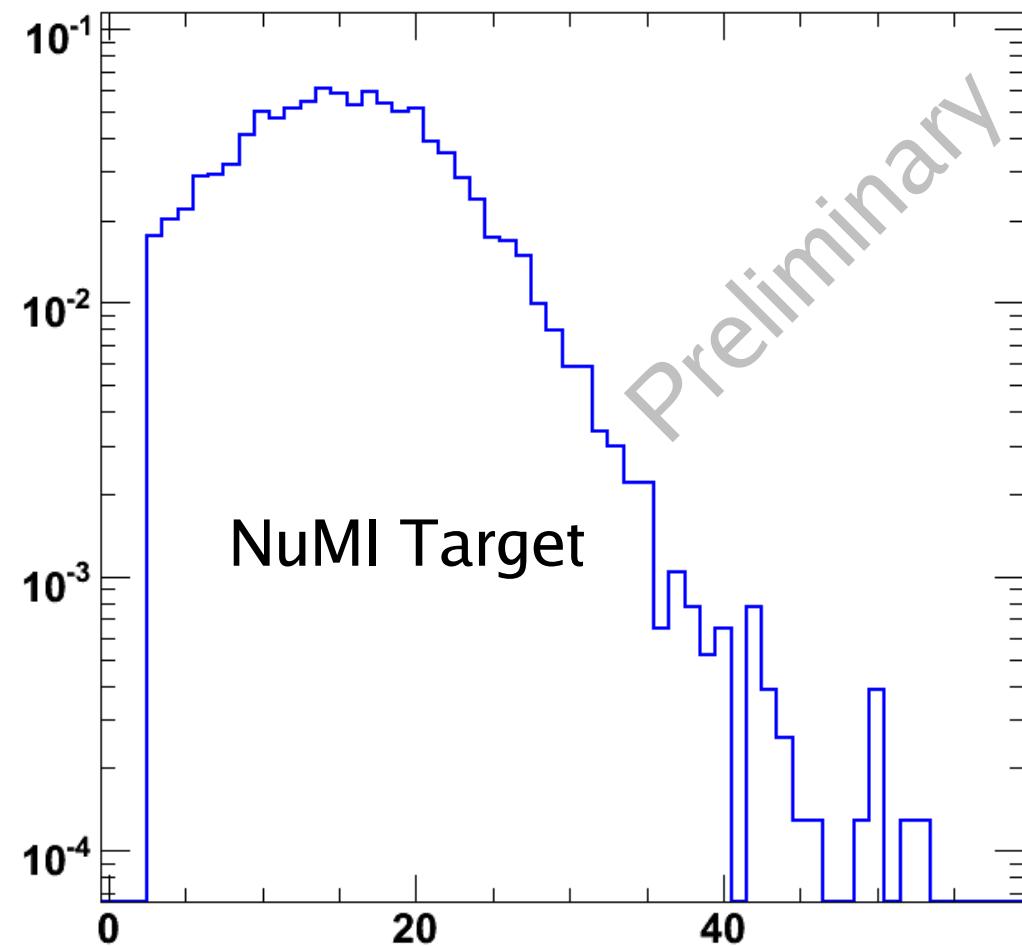
\*\*\* Data is  
only  $15 \times 10^3$   
triggered  
events  
(out of  
 $1.5 \times 10^6$   
collected  
events).

# Thin Carbon Target vs. NuMI Target

**p + C Multiplicity Distribution**

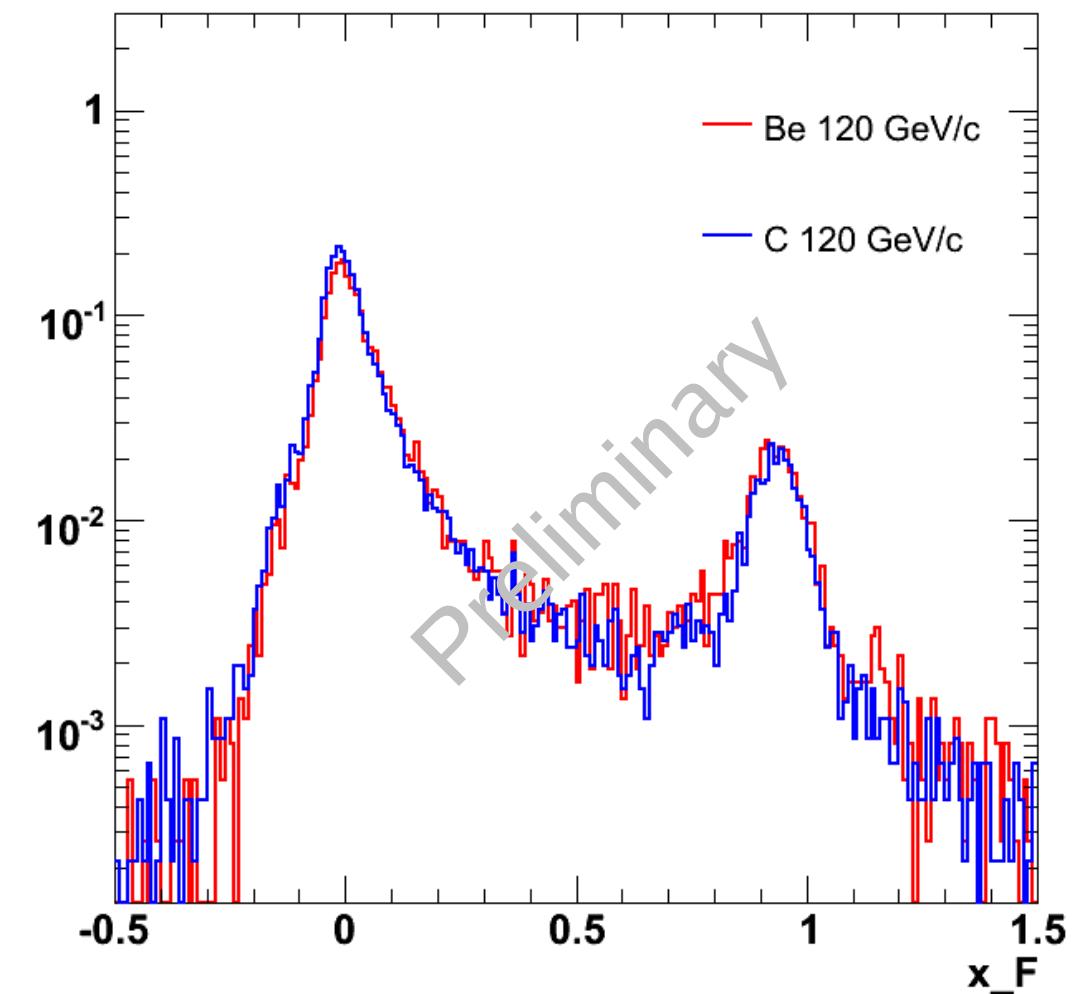


**120 GeV C + NuMI Target Multiplicity Distribution**

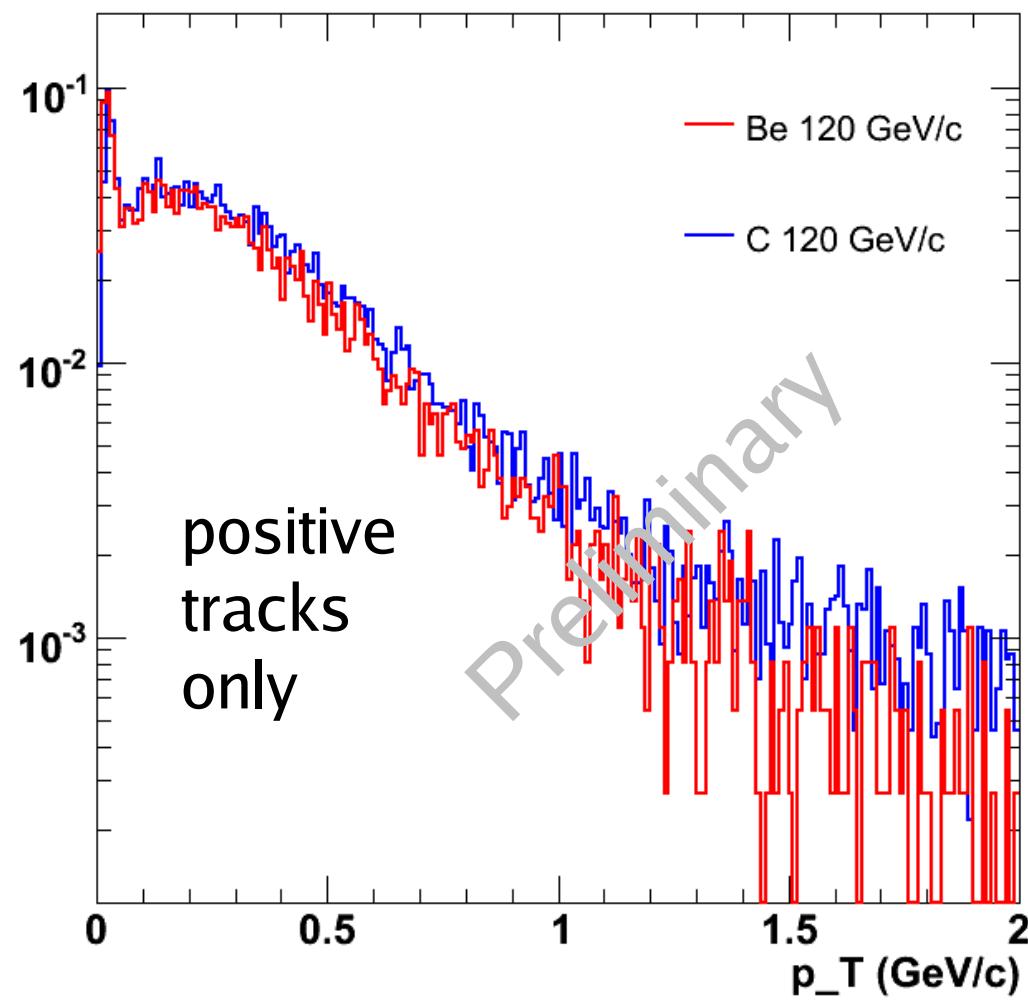


# Carbon vs. Beryllium Targets

**x\_F Distributions**



**Reconstructed p\_T Distribution**

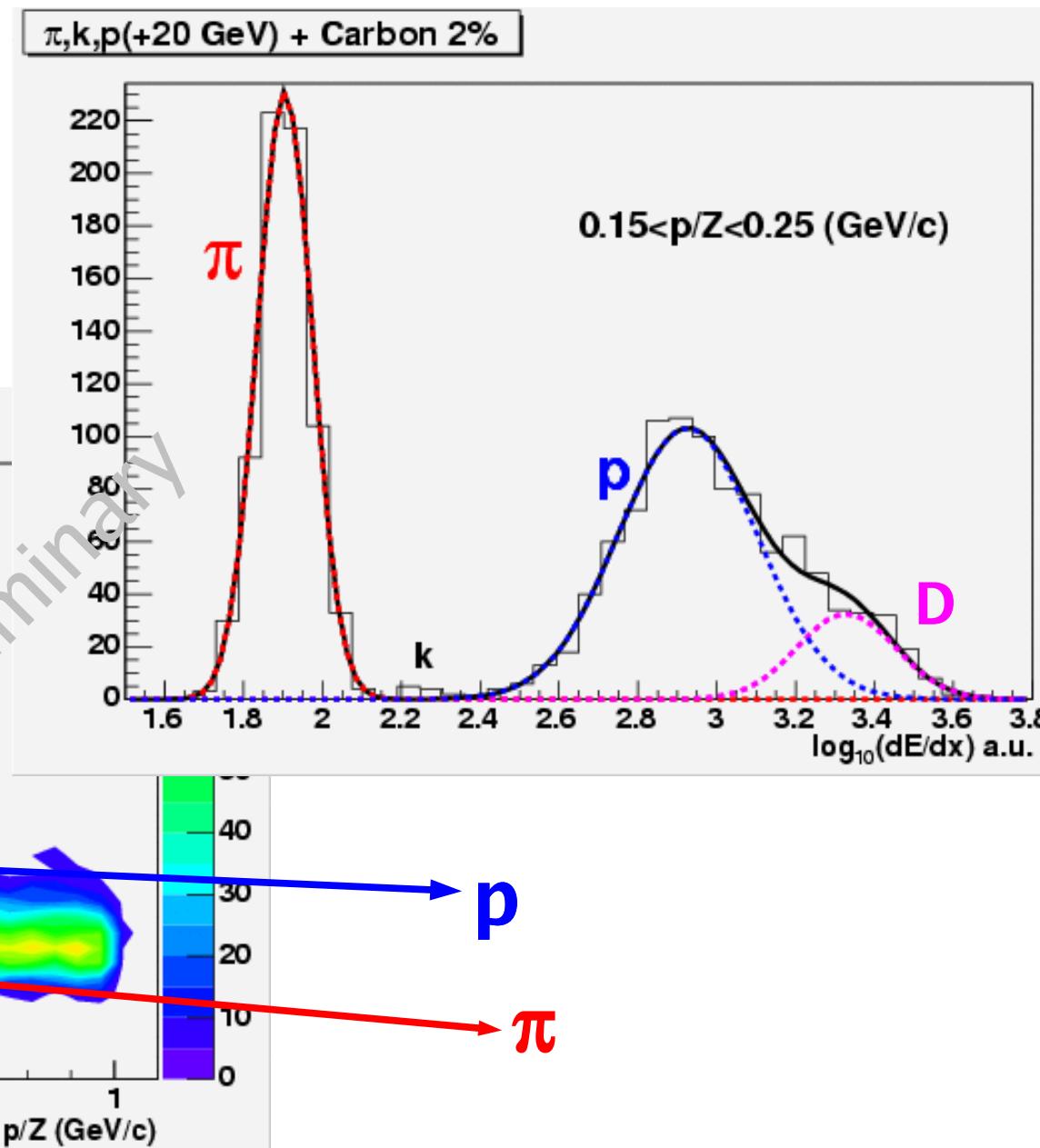
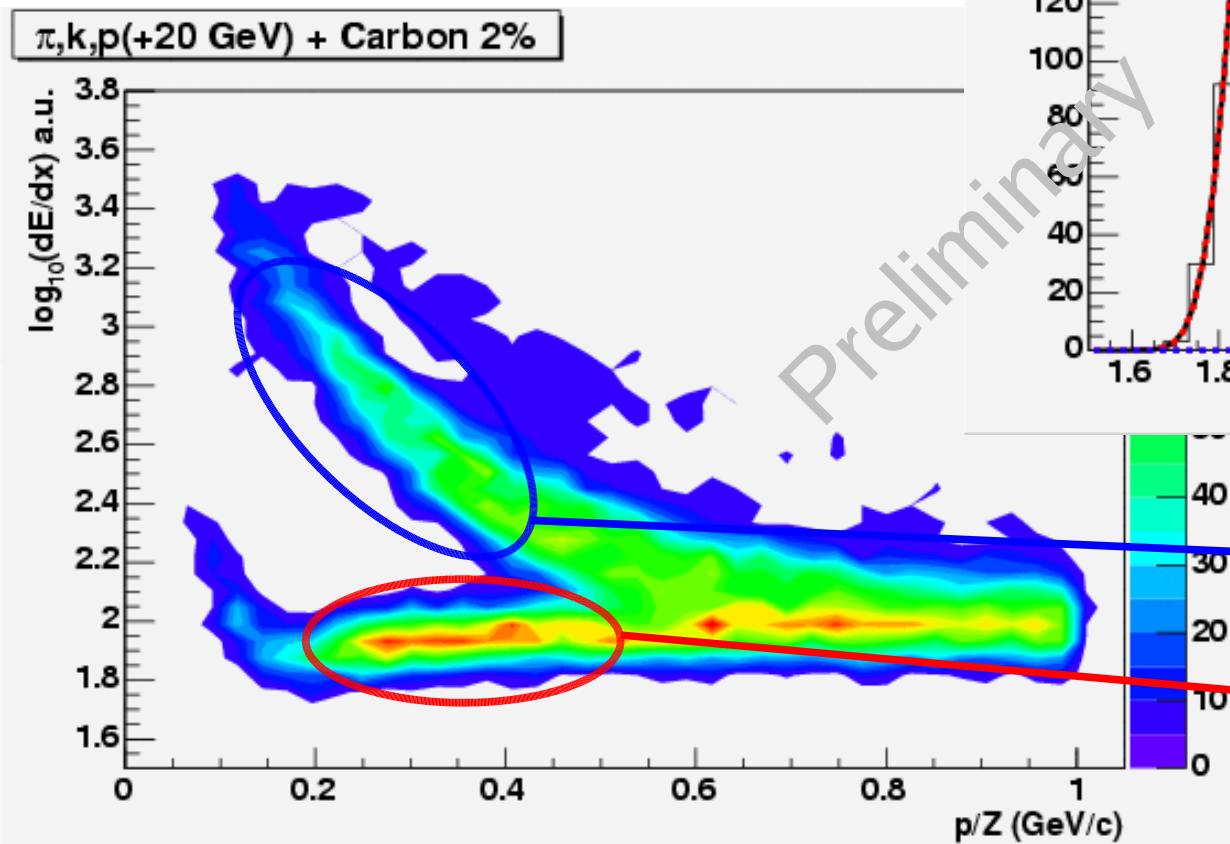


# Summary

- Hadronic cross-sections are a limiting systematic for many precision neutrino experiments; MIPP will help to significantly reduce these uncertainties.
- MIPP has so far collected  $1.5 \times 10^6$  protons on the NuMI target.
- MIPP has also collected  $\sim 1.4 \times 10^6$  p,  $\pi$  and K events on thin C target at 20, 58 and 120 GeV/c and  $\sim 1.7 \times 10^6$  events on thin Be target at 35, 58 and 120 GeV/c.
- We have made great progress in our event reconstruction
  - tracking and alignment are in good shape.
  - PID reconstruction efforts under way.
- Hope to provide inputs to MINOS in ~one year.

# TPC dE/dx PID...

- Preliminary results (uncalibrated and with poor resolution from simple track fits) very promising
- Calibration in progress



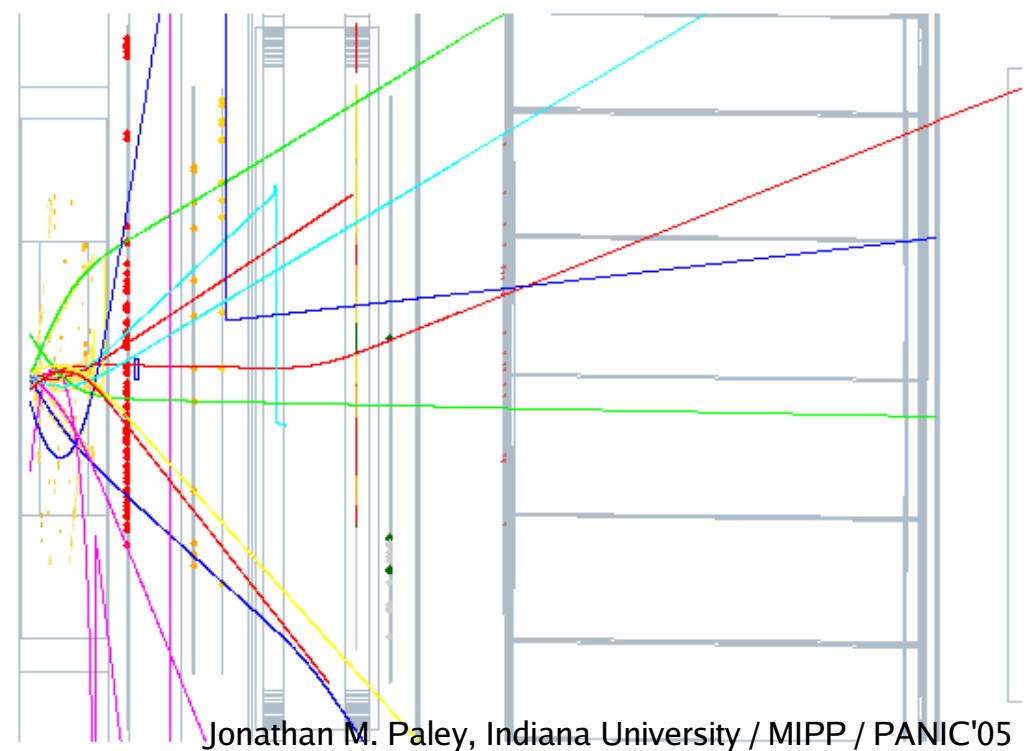
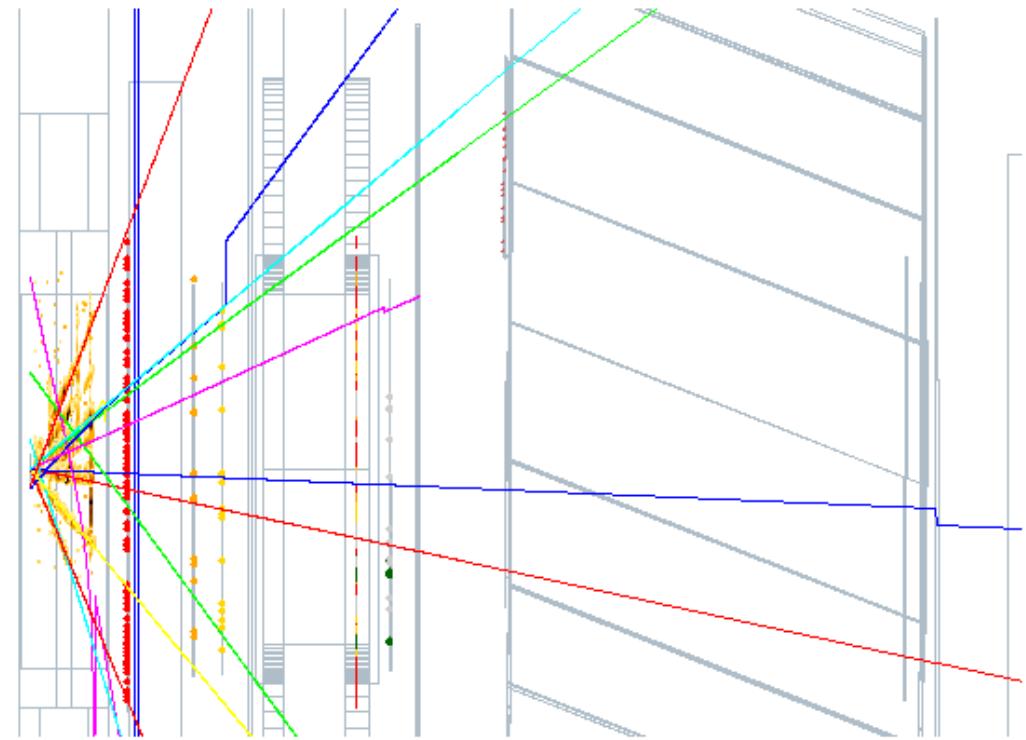
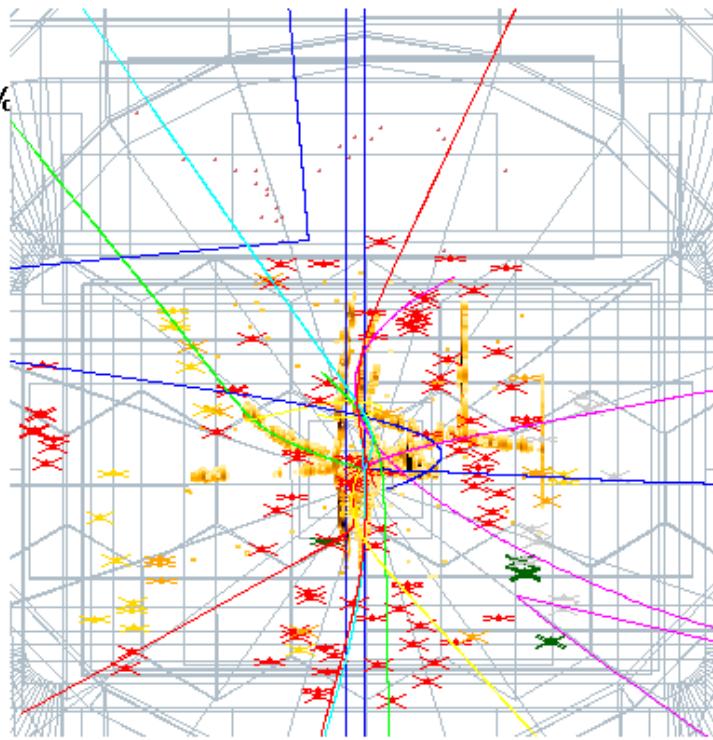
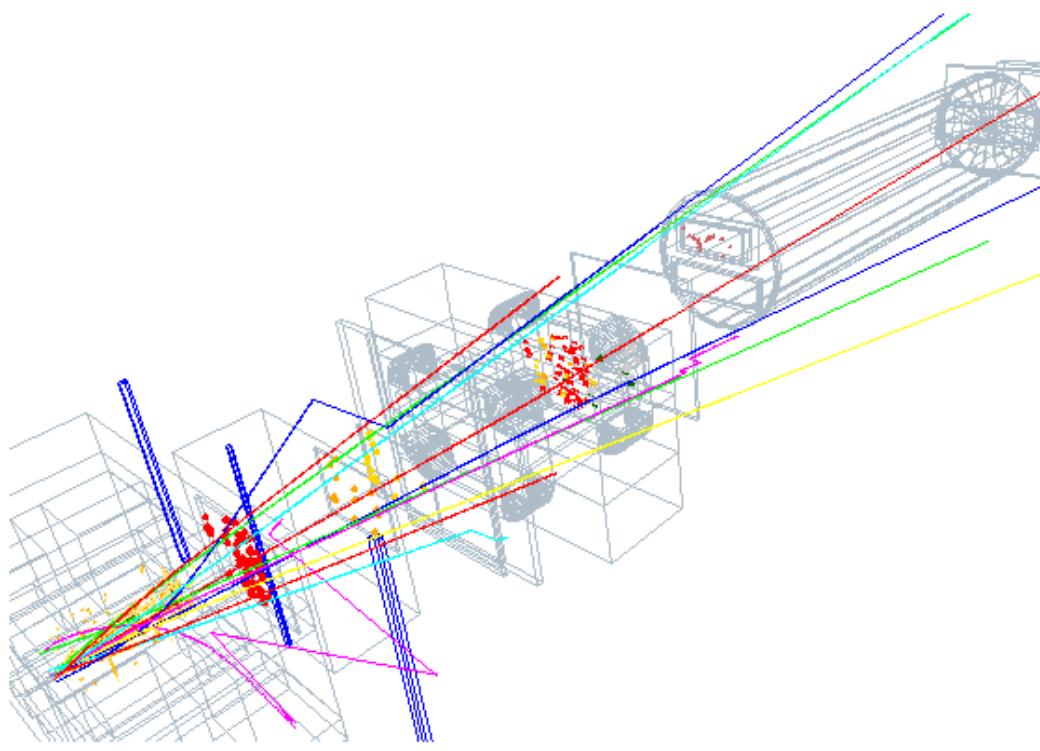
# Full Track Reconstruction

MIPP (FNAL E907)

Target: Carbon - 2%  
Run: 15860  
SubRun: 0  
Event: 19

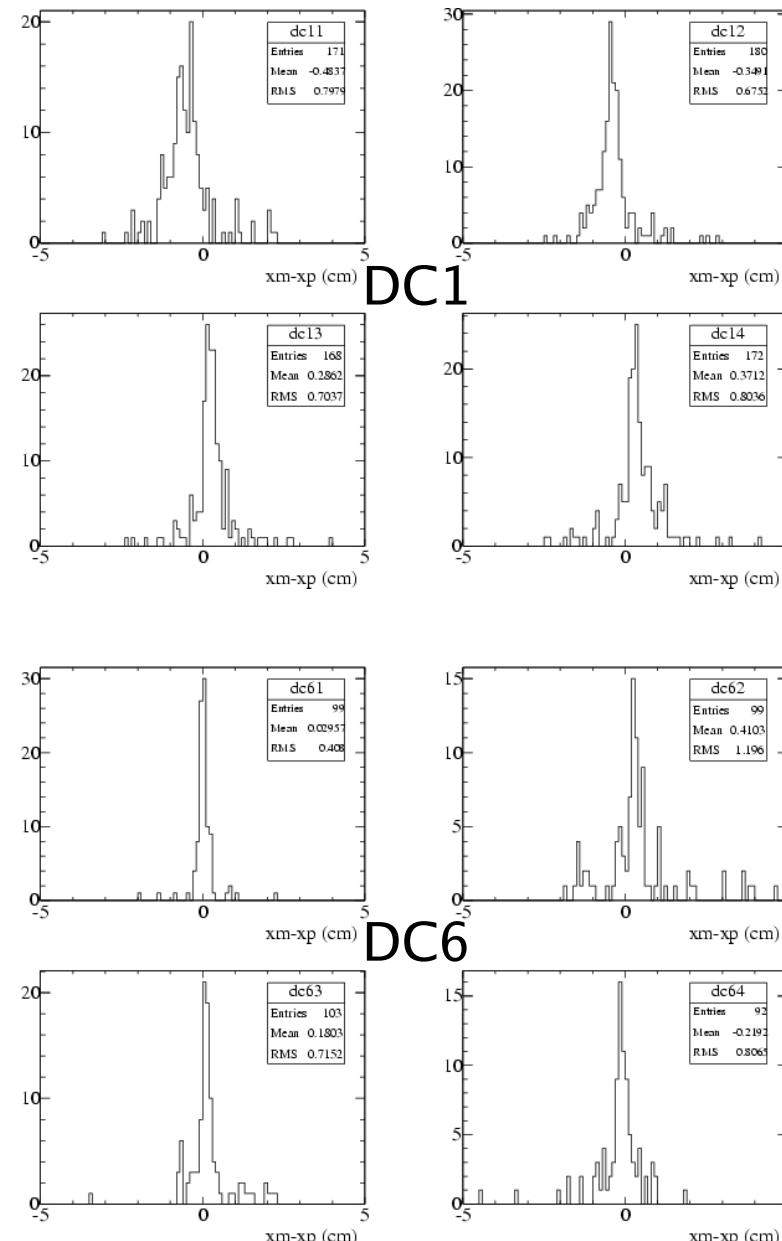
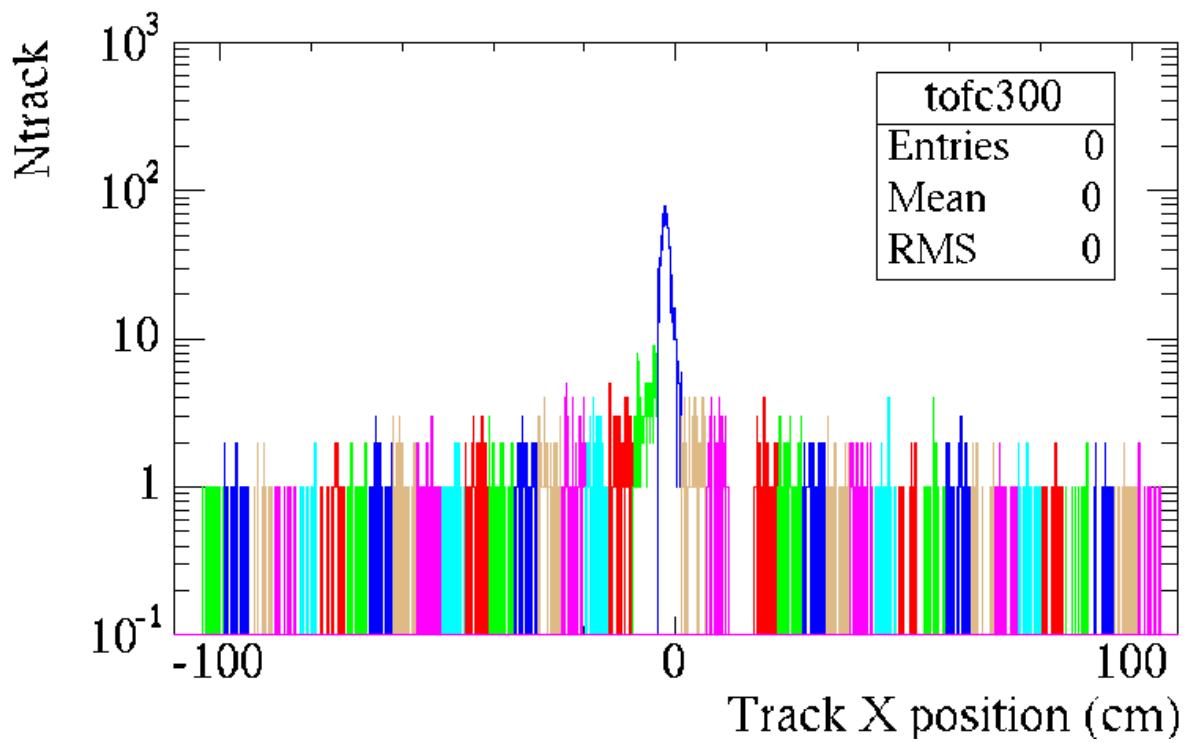
Mon Sep 05 2005  
17:55:01.888231

\*\*\* Trigger \*\*\*  
Beam  
Word: 0400  
Bits: C557



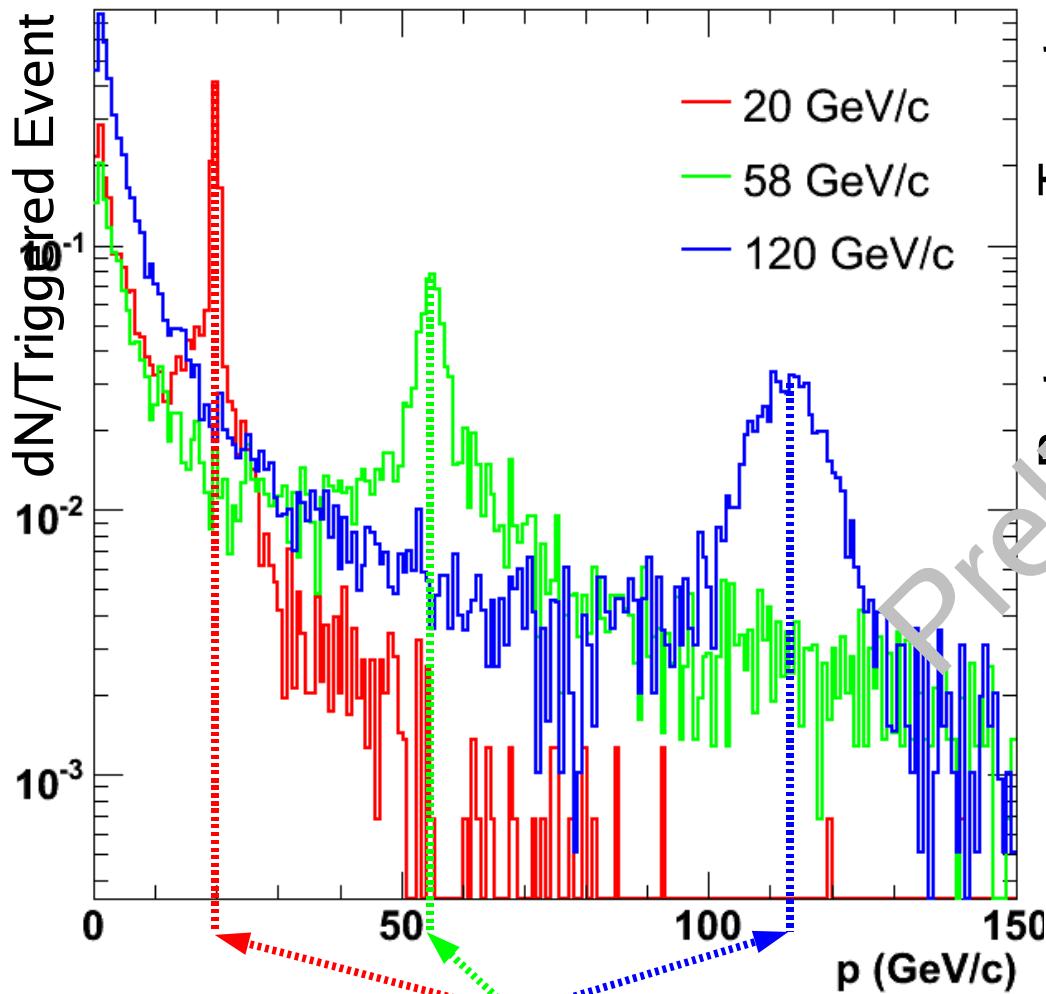
# Full Track Reconstruction

- Tracks are fit through entire length of experimental hall



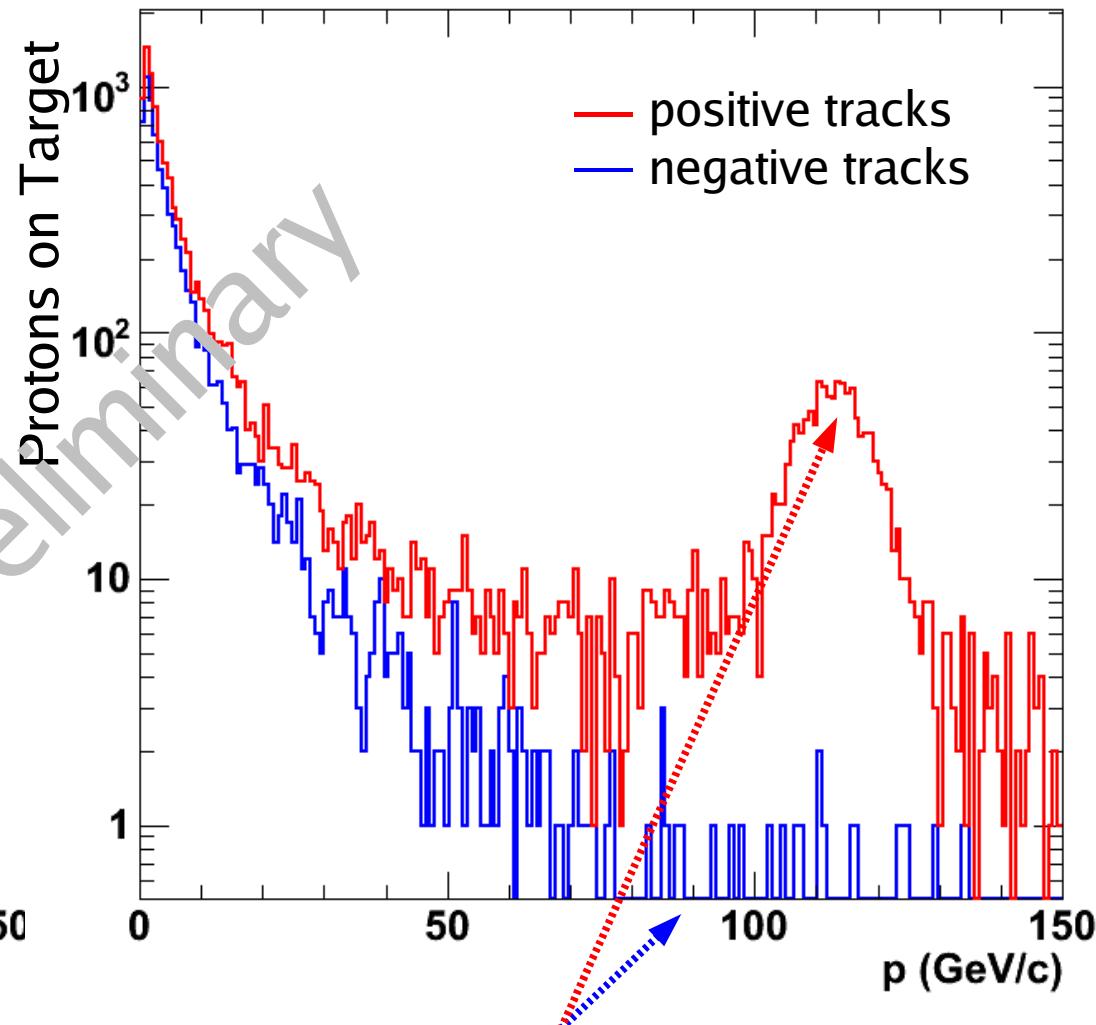
# Full Track Reconstruction

Reconstructed Momentum Distribution



Momentum differences are likely a result of uncalibrated B-fields.

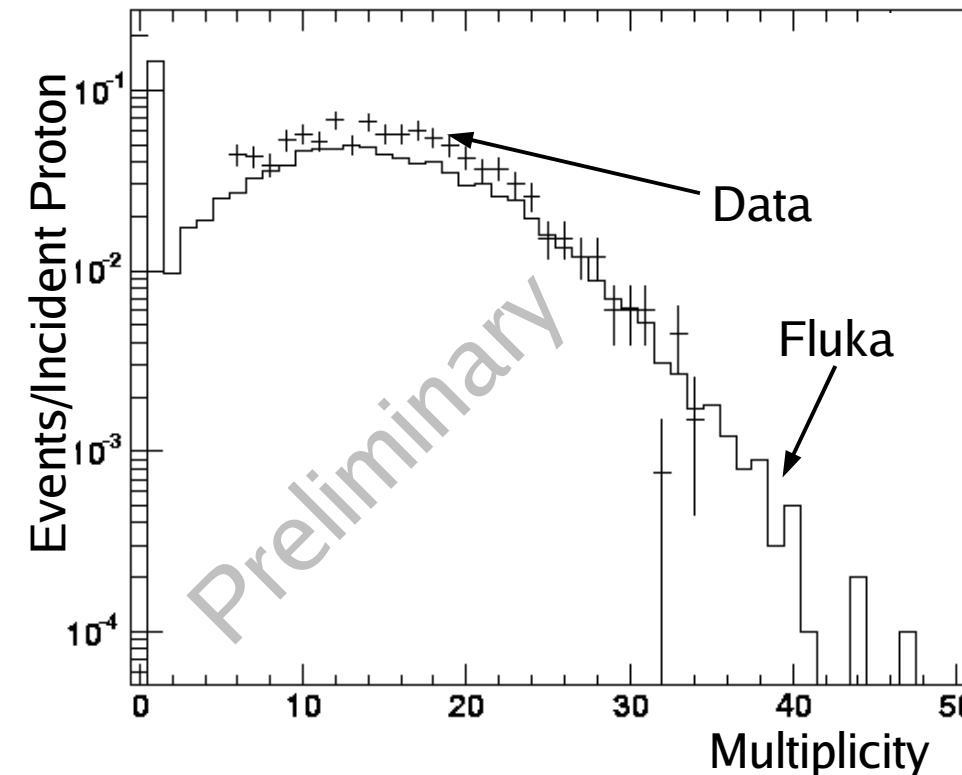
Momentum Distribution, 120 GeV p+C



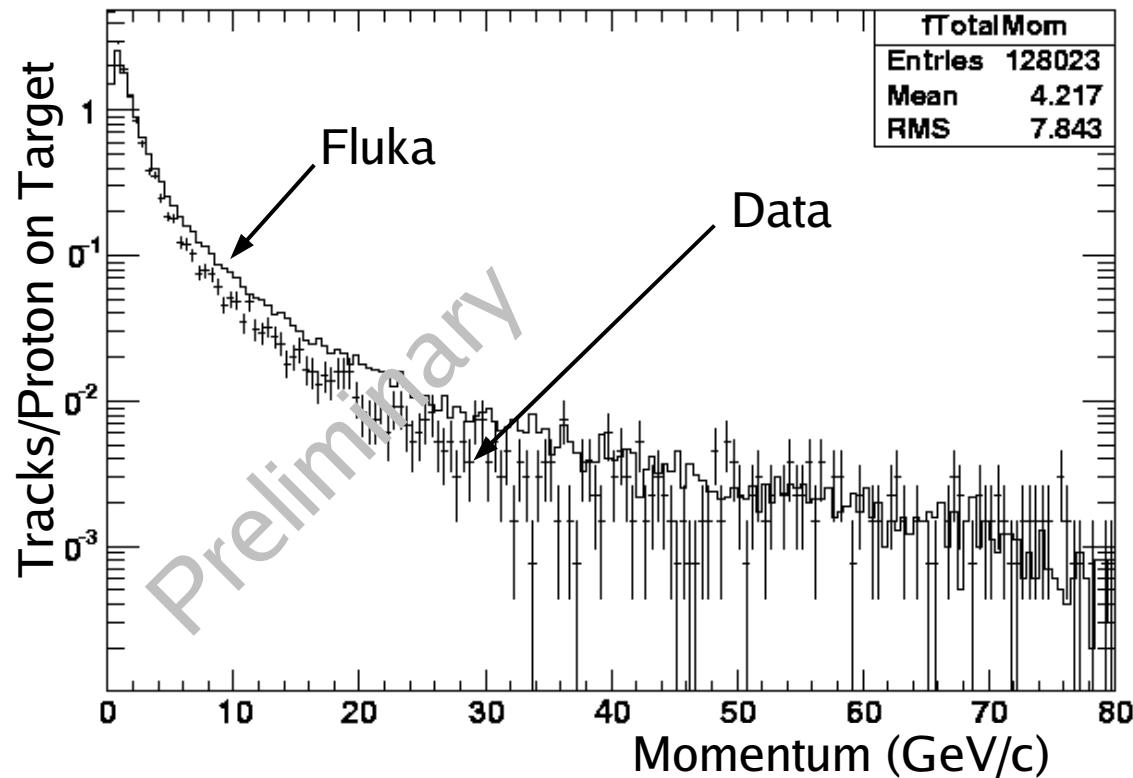
We are ~100% efficient at charge determination up to 120 GeV/c.

# Comparison of Simple Reconstruction to Fluka

NuMI Target Analysis



NuMI Target Analysis



Data is only  $5 \times 10^3$  triggered events (out of  $1.5 \times 10^6$  collected events).